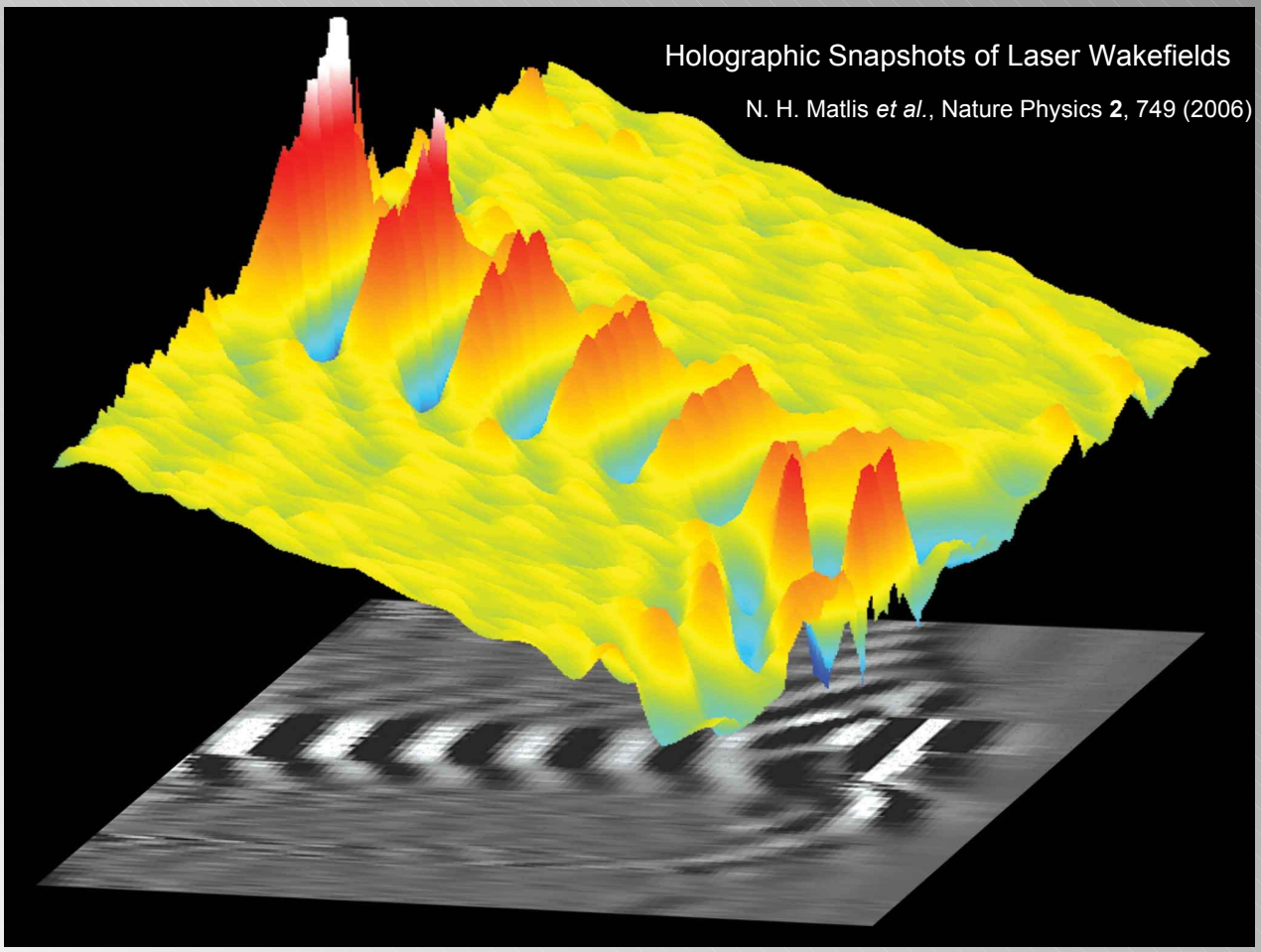
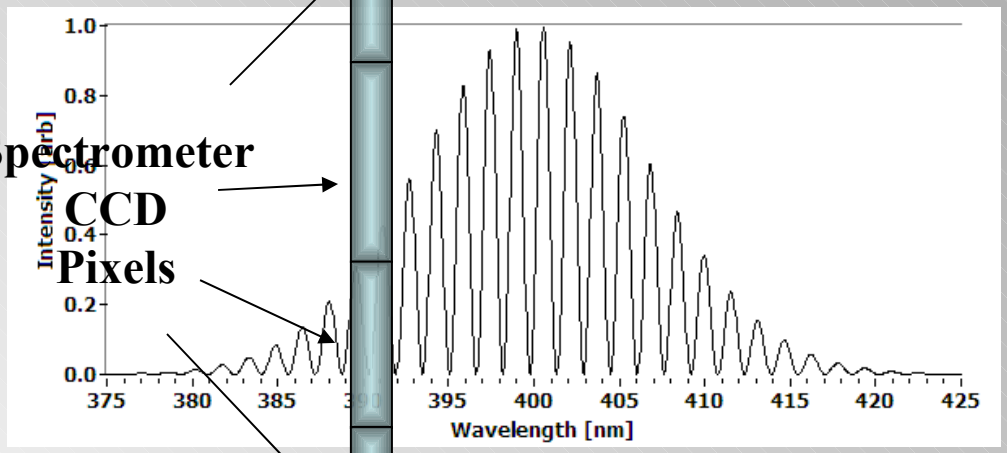
Direct measurement of temporal and radial plasma wave structure produced in a multi-bunch driven PWFA

Rafal Zgadzaj[UT], M.C. Downer[UT], P. Muggli[USC]



Interference in the Frequency Domain

Interferogram



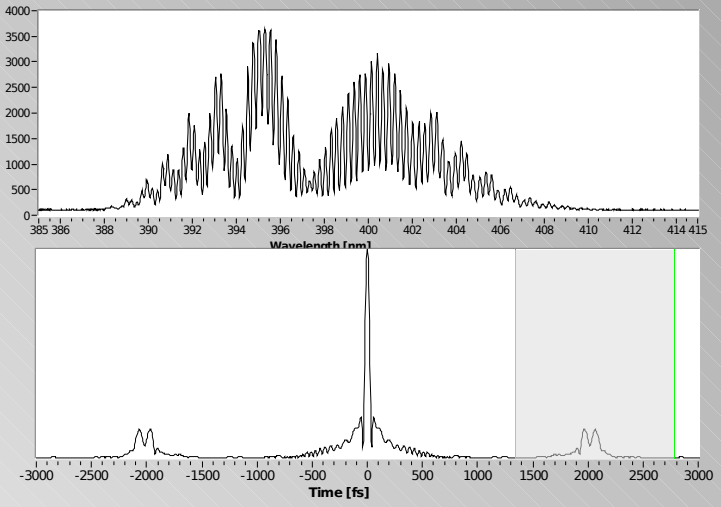
Spectrometer CCD Pixels

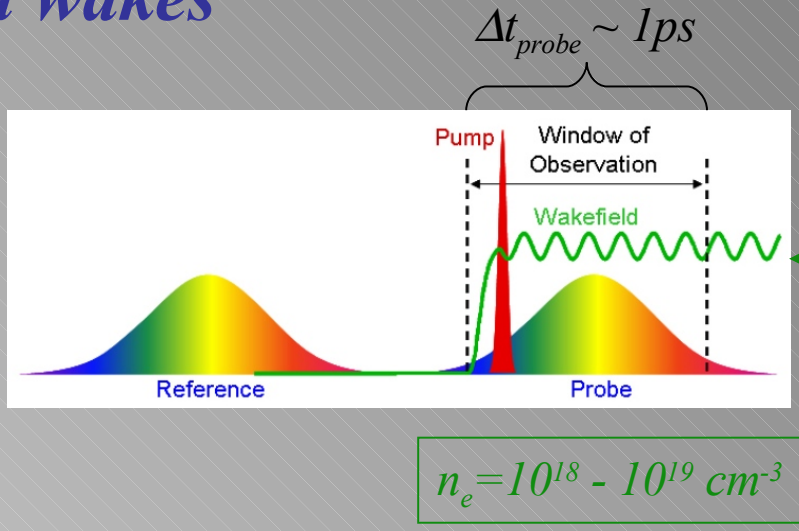
Spectrometer Grating

Pulse Duration > Pulse Separation

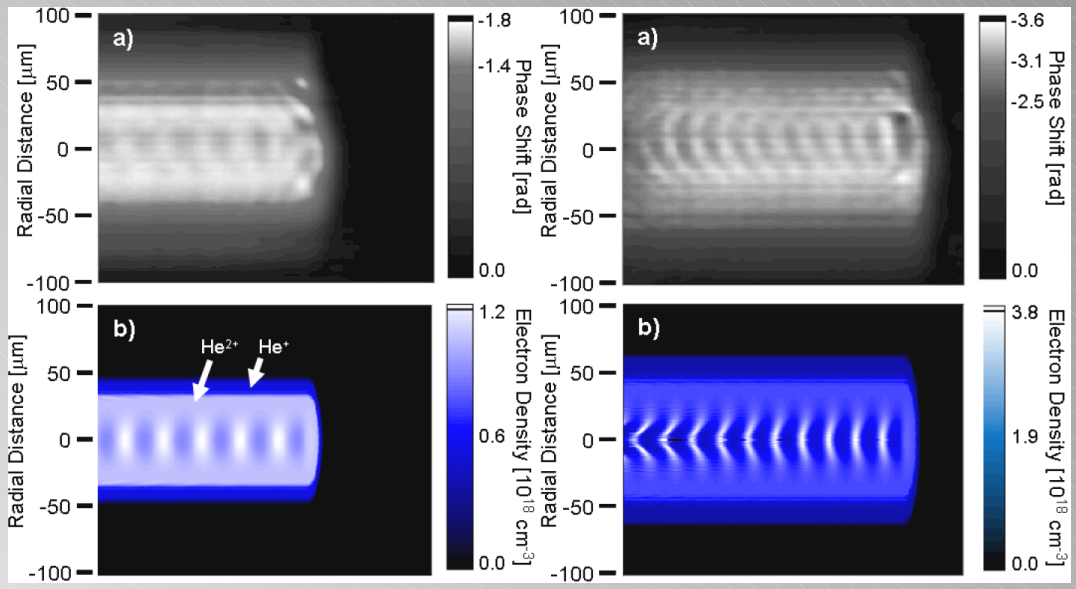
PULSES OVERLAP!

FDH – Frequency Domain Holographic reconstruction of laser-driven wakes



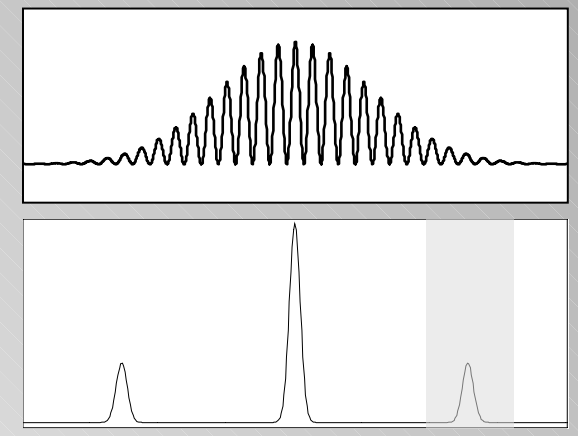


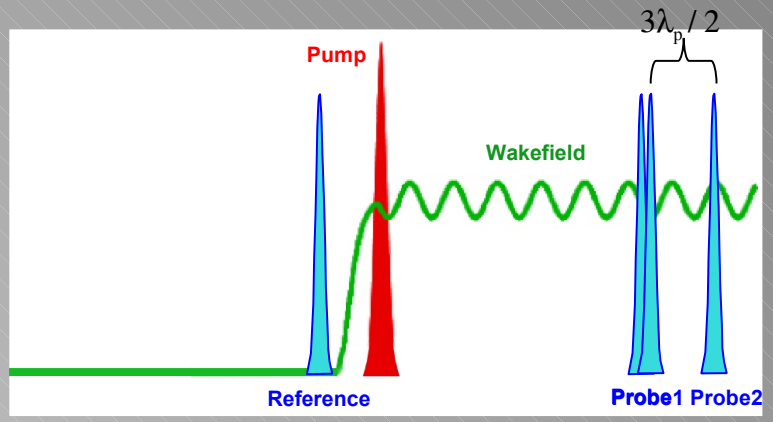
- *Single shot*
- *Temporal and transverse resolution*
- *Signal to noise good for large n_e*
- *Prone to artifacts for low signal levels*



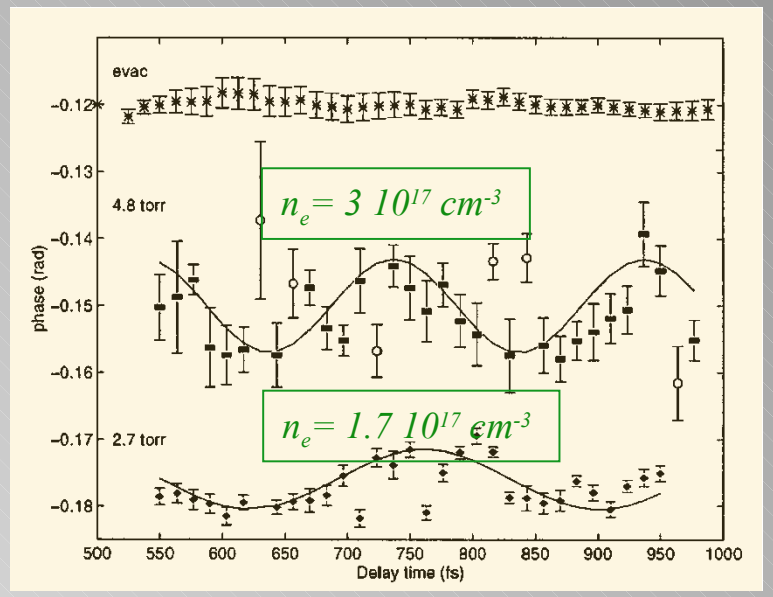
N. H. Matlis, et al., "Snapshots of laser wakefields", *Nature Physics*, **2**, 749 - 753 (2006)

FDI – Frequency Domain Interferometric reconstruction of laser-driven wakes



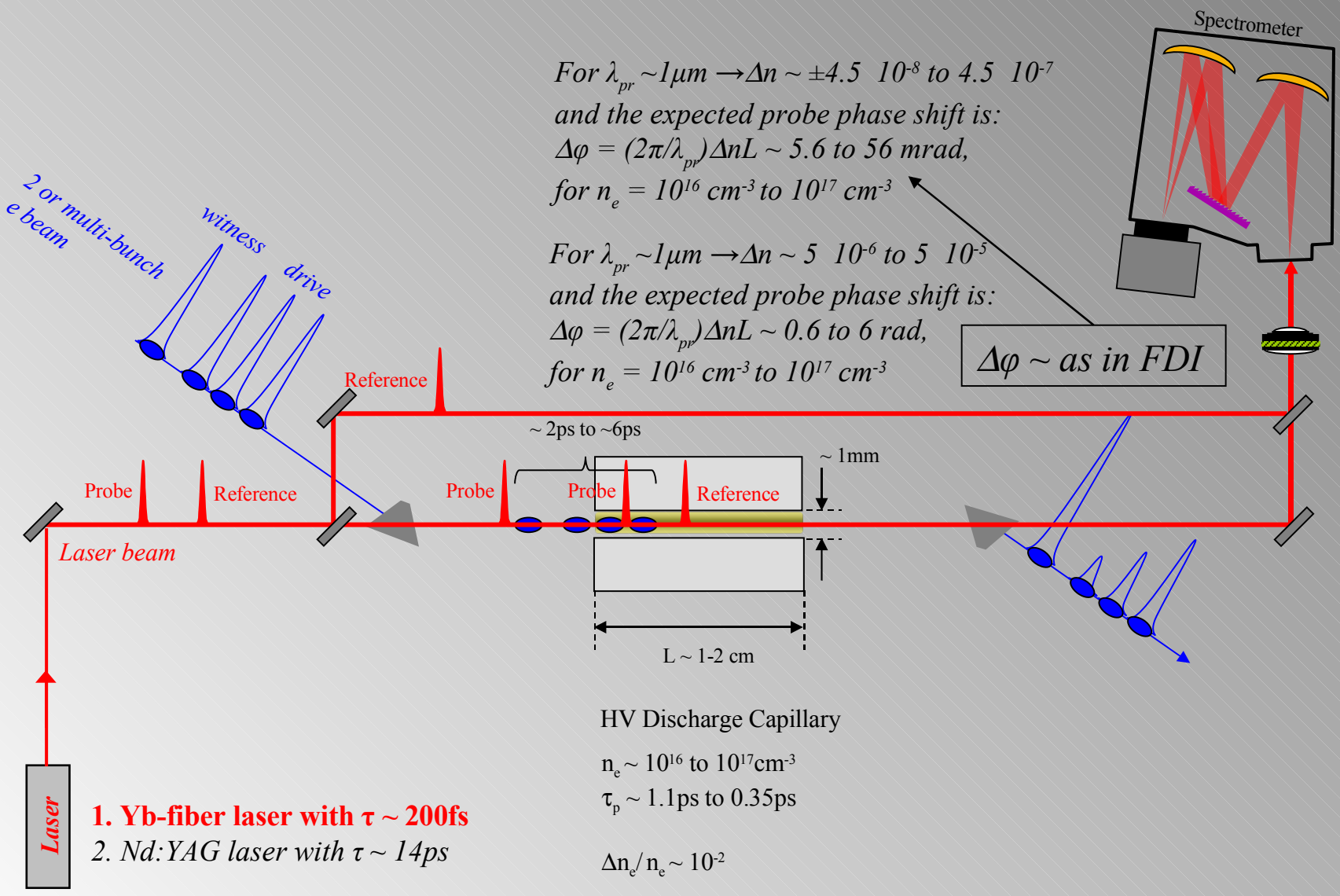


- *Multi shot*
- *Temporal and transverse resolution*
- *Very simple reconstruction*
- *Less sensitive to noise than FDH*



Siders *et al*., PRL **76**, 3570 (96)
Marqués *et al*., PRL **78**, 3463(97)
Kotaki *et al.,* Phys. Plasmas **9**, 1392 (02)

Parameters of proposed experiment



For λ_{pr} ~1μm → Δn ~ ±4.5 10^{-8} to 4.5 10^{-7}
and the expected probe phase shift is:
Δφ = $(2\pi/\lambda_{pr})$ΔnL ~ 5.6 to 56 mrad,
for n_e = 10^{16} cm^{-3} to 10^{17} cm^{-3}

For λ_{pr} ~1μm → Δn ~ 5 10^{-6} to 5 10^{-5}
and the expected probe phase shift is:
Δφ = $(2\pi/\lambda_{pr})$ΔnL ~ 0.6 to 6 rad,
for n_e = 10^{16} cm^{-3} to 10^{17} cm^{-3}

Δφ ~ as in FDI

HV Discharge Capillary

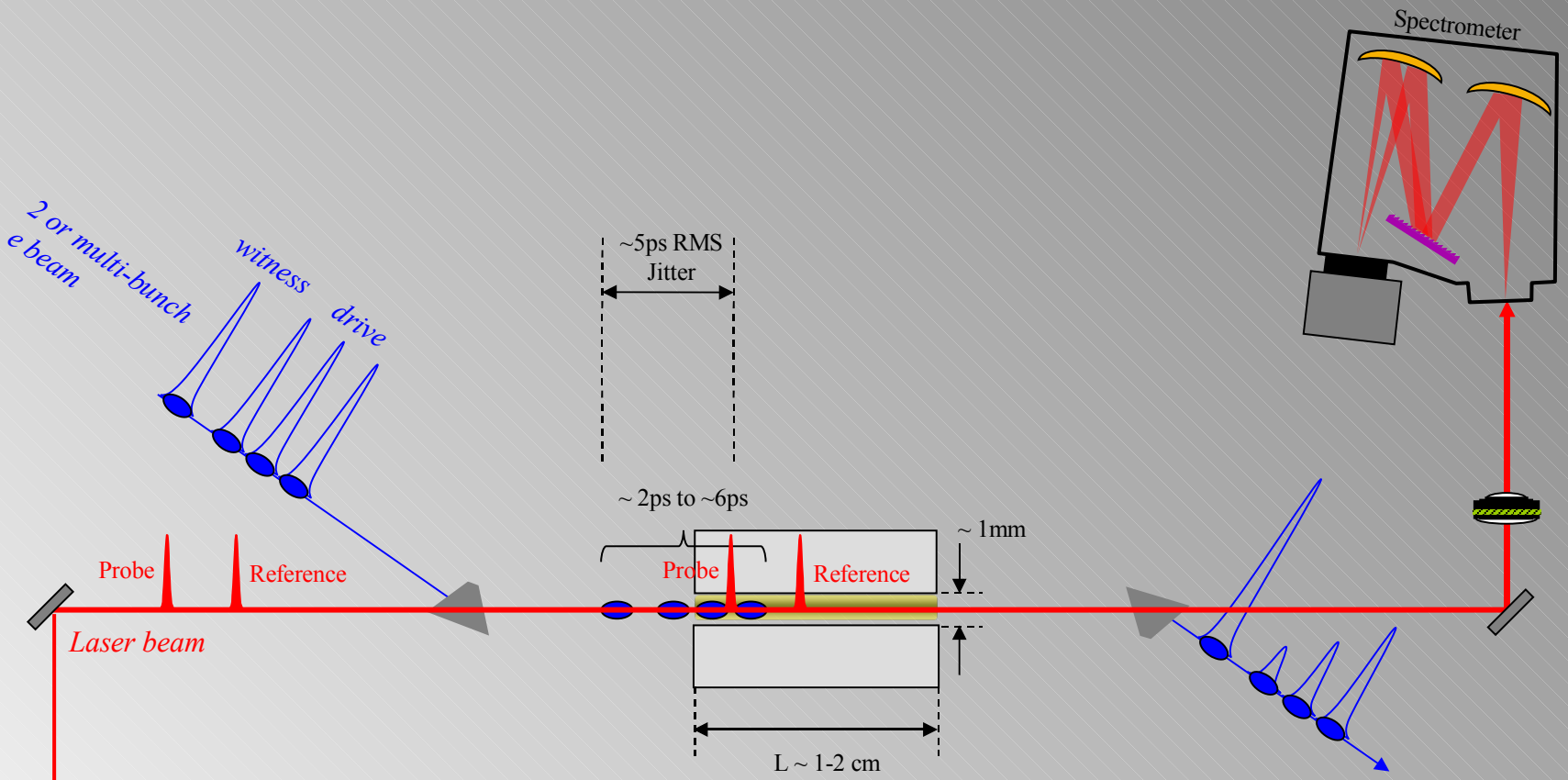
n_e ~ 10^{16} to $10^{17}$$cm^{-3}$

τ_p ~ 1.1ps to 0.35ps

$\Delta n_e / n_e$ ~ 10^{-2}

1. Yb-fiber laser with τ ~ 200fs
2. Nd:YAG laser with τ ~ 14ps

Temporal jitter between electron bunch and laser probe



HV Discharge Capillary

$n_e \sim 10^{16}$ to $10^{17} cm^{-3}$

$\tau_p \sim 1.1$ps to 0.35ps

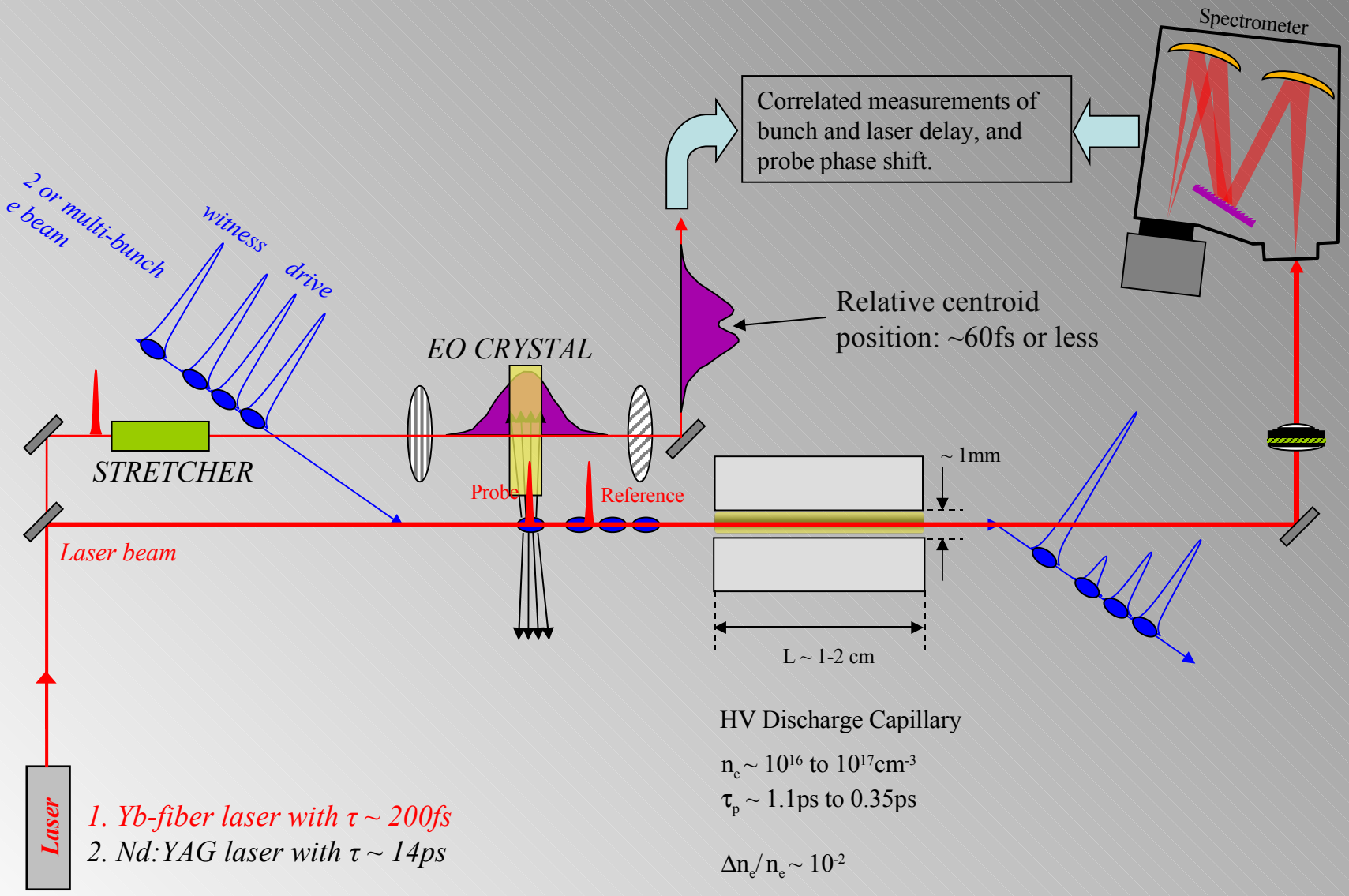
$\Delta n_e / n_e \sim 10^{-2}$

Laser

1. Yb-fiber laser with $\tau \sim 200fs$

2. Nd:YAG laser with $\tau \sim 14ps$

EO time delay measurement



HV Discharge Capillary

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$\tau_p \sim 1.1ps$ to $0.35ps$

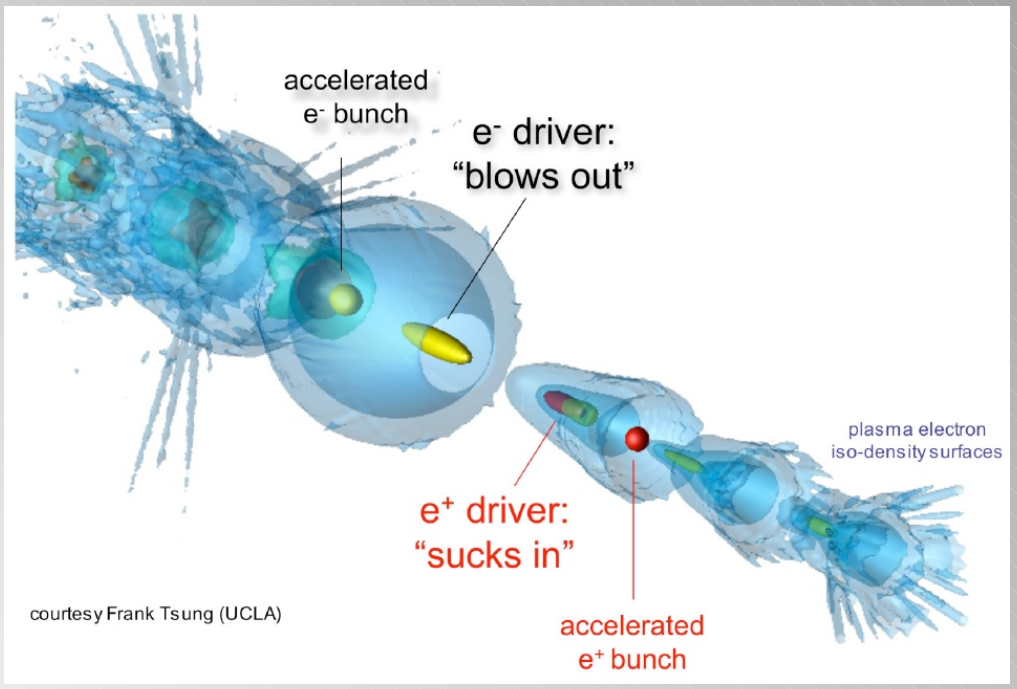
$\Delta n_e / n_e \sim 10^{-2}$

A. L. Cavalieri, "Clocking Femtosecond X Rays," PRL **94,** 114801 (2005).

Conclusion

- *We propose an optical diagnostic of the longitudinal and transverse structure of PWFA*
- *Initial FDI measurements with possible subsequent FDH if background is sufficiently low.*
- *Correlation of local plasma wave and microbunch amplitudes*
- *Direct observation of resonant wake enhancement in the multibunch experiments*

- *Direct observation of different structures of electron and positron driven wakes.*



Proposed Schedule

- *Year 1*
  - *Some optical setup does not require the electron beam and may be performed outside of regularly scheduled beam time.*
  - *We suggest 3 initial 2 week runs with 2 month intervals for the following:*
    - *Spatio-temporal alignment of e-beam and laser probes*
    - *Implementation and evaluation of noninvasive jitter recording*
    - *Preliminary FDI alignment and measurement with reference pulse bypassing plasma.*
  - *We suggest 3 subsequent 2 week runs with 2 month intervals for the following:*
    - *Measurement of beam driven wakes with various spatio-temporal formats which may take place in part or completely along with project AE31 (headed by P. Muggli) and aimed at studying properties of accelerated electrons in beam driven wakes.*
- *Year 2*
  - *We anticipate between 4 and 6 additional two week experimental runs to explore the full range of drive pulse formats and plasma densities. Again, some or all of these runs may be simultaneous to Project AE31.*